DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C. 20332-5000

REPLY TO
ATTN OF: LEEE

SUBJECT: Engineering Technical Letter (ETL) 88-3: Design Standards for Critical Facilities

TO: HQ PACAF/DEE/DEO
HQ MAC/DEE/DEM
HQ SAC/DEE/DEM
HQ TAC/DEE/DEM
AFIT/DET/DEM
HQ AFSPACECOM/DEE
CEEC-ES
NAVFAC Code 04/05
HQ USAFE/DEE/DEX/DEM/DES/DE
HQ AFSC/DEE/DEM

1. Purpose: Air Force facilities which are essential to the success of an installation's mission, in areas where the threat of conventional warfare exists, must remain operational during periods of attack or threat of attack. Conventional facility design and utility systems are vulnerable to effects of conventional warfare. Central utility distribution systems, in particular, are vulnerable under attack. It will be assumed for the purposes of this ETL that the central distribution systems (electric, water, wastewater, heating and cooling) will not be in service as a result of a conventional attack. To increase the survivability of these essential or critical facilities, facility structural hardening and back-up or independent utility systems are to be considered for proposed new critical facilities in areas where the threat of conventional warfare exists. The threat of conventional warfare is assumed to exist in those areas outside the CONUS, particularly in the European and Asian theaters where host countries border hostile territories. For the purpose of this ETL, critical facilities will be those facilities designated as Hardened-(HD) or Semi-hardened (SH) in Table I, para 3b(1) of Annex L, War Mobilization Plan, Volume 1 (WMP-1) or other facilities as designated by the MAJCOM. The criteria contained in this ETL is recommended, not mandatory, for all proposed new critical facilities. Implementation of this criteria will be up to the discretion of the MAJCOM depending on mission requirements, the applied threat and the degree of reliability/operability to be obtained by the facility. This criteria may also be applied to the upgrading of existing critical facilities where deemed appropriate by the MAJCOMs to satisfy mission objectives. The length of the contingency period during which the critical facility must remain operational will be determined locally based on the particular mission of the facility as established in the installation's Contingency Response Plan or other appropriate mission requirements. This ETL is to be implemented in accordance with AFR 8-7, Air Force Engineering Technical Letters (ETLs).

2. Effective Date: This ETL is to be effective with the design of the FY 91 MCP.

3. Referenced Publications: This ETL is authorized in accordance with AFR 8-7, Air Force Engineering Technical Letters (ETLs) dated 9 Jan 1986. Other applicable publications are as follows:

a. War Mobilization Plan, Volume 1 (WMP-1), Annex L.

b. 1987 ASHRAE Handbook, HVAC Systems and Applications, Chapter 27, Environmental Control for Survival, and Chapter 52, Sound and Vibration and Control.

c. TM 5-855-1, Fundamentals of Protective Design for Conventional Weapons, U.S. Department of Army, 1984.

d. Design of Protective Structures for Conventional Weapons (Draft) Air Force Engineering and Services Center, Sept. 1987.

e. AFWL-TR-74-102, Air Force Manual for Design and Analysis of Hardened Structures, Air Force Weapons Laboratory, 1974.

f. AFM 88-22, Structures to Resist the Effects of Accidental Explosions.

g. AFR 88-15, Criteria and Standards for Air Force Construction.

h. Marquis, J.P., and Paez, T.L., Manual for Use of Shock Response Spectra in Assessing Equipment Survivability and Shock Isolation Requirements for Arch Structures, AFWL-TR-84-45, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, March 1985.

i. Marquis, J.P., and Paez, T.L., Manual for Use of Shock Response Spectra in Assessing Equipment Survivability and Shock Isolation Requirements for Bermed Rectangular Structures, AFWL-TR-86-35, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, March 1986.

4. Description/Implementation: Design concepts/considerations. The following provisions are recommended in the design of new critical facilities.

a. Structural:

(1) Protective construction measures should be incorporated into the design of facilities which need to be protected from the effects of conventional warfare. Protective construction is defined as those passive measures which can be used to reduce or nullify the effects of an attack on an installation or enhance the

recouperability after an attack or both. It includes strengthening, revetment, dispersal, camouflage, concealment and deception of structures.

(2) Air Force policy and criteria for conventional hardening is included in the War Mobilization Plan (WMP-1) Annex L. This policy defines level of hardening and prioritization of facilities.

(3) The damaging effects of conventional weapons are many. The predominant effects are due to blast, cratering, ground shock, fragmentation and penetration. The structure shall be designed for normal static (dead and live), wind and seismic loading as well as dynamic loading associated with specified weapons threat. For overseas bases, the static, wind and seismic loading shall comply with the host nation standards. The structure shall be designed for the severe loading condition, static or combined static and dynamic loads. The dynamic analyses shall consider both localized weapons effects on individual structural elements and overall weapons effects on the entire structural system.

(4) The procedures for analyzing and designing protective structures are outlined in the following references: TM 5-855-1, Fundamentals of Protective Design for Conventional Weapons, U.S. Department of the Army Design of Protective Structures for Conventional Weapons, (Draft), Air Force Engineering and Services Center, Sept. 1987, and AFM 88-22, Structures to Resist the Effects of Accidental Explosion. In addition to these references, additional technical information pertaining to protective construction is available through the Air Force Weapons Laboratory (AFWL/NTE) and the Air Force Engineering and Services Center (AFESC/RD). The following basic design steps shall be considered in analyzing and designing these facilities:

(a) Define the operational requirements of the facility.

(b) Develop a baseline configuration of the facility.

(c) Assign the threat level to the facility.

(d) Calculate the loads expected from the threat weapons.

(e) Design structural elements to resist the calculated loads.

(f) Analyze the facility response.

(g) Iterate between steps (e) and (f) to reach a final design.

(5) For structures which house equipment, the designer must consult with the engineer in charge of placing the equipment to determine what shock mitigation or isolation features are required. For example, if there is a large quantity of sensitive equipment which can be placed closely, together, it may be cheaper to provide an isolated floor in one area than try to isolate individual pieces of equipment.

(6) Critical facility utilities systems should receive the same degree of protection or hardening as that of the facility served.

b. Electrical:

(1) Electrical systems for critical facilities should be designed for continuity and,/or quick return to service. An engineering evaluation of each situation should be made to determine the most cost effective methods based on operational requirements and local conditions. The evaluation should, as a minimum, consider the following:

(a) Threat assessment and anticipated duration of the contingency period.

(b) High reliability power requirements as specified by AFR 88-15, Chapter 15, Section 3. Additional provisions such as equipment hardening may be required to enhance survivability.

(c) Required operating scenario including procedures, equipment and personnel necessary for transferring to emergency/back-up sources and restoration to normal configuration.

(d) Possible consolidation of requirements if the facility is in close proximity to other critical facilities or power generation sources. However the survivability and reliability aspects of any distribution lines as well as the power source(s) must be considered.

(e) Availability of Mobile Electric Power Systems (MEPS) and operations/maintenance personnel.

(f) Fuel replenishment capabilities for fixed and mobile generators

(g) Possible effects on existing equipment and load flow, short circuit and coordination studies.

(2) Unless otherwise determined by engineering evaluation or specifically required by other design standards (military handbooks or DOD manuals), the following features should normally be provided:

(a) Distribution systems inside critical Facilities should have dual feeders or at least loop feed capabilities for the critical technical loads.

(b) Protection from transients such as lightning and switching surges should be provided at the distribution, station, and facility levels. This is necessary to provide graduated degrees of protection within the capabilities of the actual transient protection device (TPD) available for use at each level. Silica carbide gap type, metal-oxide varistor gapless type, silicon avalanche, zener diodes, gas tubes, balun coils, and other miscellaneous types which are now available may be considered, as well as future approved types when proven reliable.

(c) Diesel engine power generation plants for emergency/back-up use should be designed as follows:

1. Include a maintenance and a standby unit for plants supporting multiple facilities. In the case of a single engine plant dedicated to an individual facility, this maintenance and/or standby capability may be provided by MEPS when equipment availability and operational requirements permit. A quick-connect plug should be provided on the exterior of the critical facility so the installed generator can be bypassed by the MEPS when necessary.

2. Size the plant for the total connected technical (operational) load plus ten to thirty percent spare capacity for unanticipated future loads. In the case of multiple engine plants, consider providing space for an additional unit.

3. Provide heat exchanger (co-generation/total energy) capability if facility heat is required. See para 4c(1).

4. Plants should be fully automatic with manual override capability and electronic controls designed to survive surges and transients. Load shedding should not be required for new plants but may be considered for upgrade or retrofit of existing plants.

5. Central fuel storage should be sized based on the expected duration of the contingency and local fuel replenishment capabilities. Each unit should have its own day tank and the fuel system should allow for full operation and isolation of each unit.

6. The emergency generator plant or shelter should be hardened to the same degree as the facility served. The availability and survivability oF the engine coolant and compressed air starting systems should also be considered.

(d) Use circuit breakers rather than fuses if their interrupting capability is adequate. If fuses are necessary, ensure spares are on hand and readily replaceable. Switchgear should include an extra circuit breaker of each frame size so as to be readily available in an emergency. Consider leaving extra length on critical conductors to allow rerouting to an adjacent breaker or fuse.

(e) Emergency lighting should be provided for all critical areas. Some emergency lights should be portable (maintenance free) battery operated) to permit relocation or replacement. Spotlight type lights in hallways and Passages should not be placed above doors or at other locations where they will blind those approaching.

(f) All electrical systems should be designed with devices and components which are readily available and have standard replacement parts. Identify and stock critical electrical supplies, parts, devices and components. If necessary, establish special stock levels and/or benchstock.

c. Heating, Ventilating and Air Conditioning (HVAC) Systems. Design criteria for heating, ventilating, and air conditioning systems is identified in the "1987 ASHRAE Handbook, HVAC Systems and Applications", Chapter 27, Environmental Control for Survival. Systems need to be selected for the critical facilities applied threat with the following additional criteria:

(1) Heating: The primary back-up heat system should include use of diesel engine generator cooling system heat. System design should be kept as simple as possible with a minimum of moving parts and connectors. Existing components of the building HVAC systems should be used whenever possible, and conventional heat exchanges and components shall be used where new items are required. A supplementary hack-up system should include electric radiant reheat for use when the generator is not operating at full load conditions. Electronic controls should be fully automatic, and should have manual override or by-pass capabilities. In regions that experience prolonged periods of sub-freezing temperature., minimum heat would be provided to prevent freezing of pipes, storage tanks, coils, radiators, etc., in those areas of the facility that will not be utilized during the periods of a central plant outage. Heat can be provided from the diesel cooling water, or through electrical resistance heating elements.

(2) Chemical-Biological-Radiation (CBR) Filters: Filter and prefilter units for protection against biological and chemical warfare agents that are installed in the environmental control system should be the standard modular type filters use~ in the Survivable Collective Protection System (SCSP) II. Standardization of the filters will support the maintainability, supply, spare replacement and interchangeability requirements.

d. Shock Isolation of Equipment. All equipment which may be adversely affected and impact mission objectives as a result of shock transfer should be shock isolated as outlined below:

(1) Equipment Mounting Procedures: General guidelines and techniques for determining the response and mounting requirements for equipment installed in structures exposed to blast and shock effects may be found in the following references: TM 5-855-1, Fundamentals of Protective Design for Conventional Weapons, Department of the Army (1985), Chapters 11 and 12, and AFWL-TR-74-102, Air Force Manual for Design and Analysis of Hardened Structures, Air Force Weapons Laboratory (1974), pages 906-1017. The Army manual gives the following general steps to follow when installing equipment in protective structures:

(a) Step 1 - Equipment Classification - designers must first classify the equipment as follows:

1. Mission-critical equipment that must function during and after each shock (Criticality A).

2. Mission-critical equipment that does not have to function during each shock but must function following each shock (Criticality B).

3. Equipment not critical to the mission that does not have to function during or following each shock (Criticality C). Criticality A and B equipment must be protected against shock. Criticality C equipment will be hard mounted and securely attached to the building structure to prevent hazards to personnel or mission-critical equipment.

(b) Step 2 - Determine In-Structure Shock Environment-Computer and plot the horizontal and vertical in-structure shock response spectra (SRS). A method for finding in-structure SRS is given in Chapter 11 of the Army Manual. It should be pointed out that the severity of the in-structure environment is dependent on weapon yield and location, soil conditions, and the configuration of the shelter. The Air Force Weapons Laboratory (AFWL/NTE) has developed SRS curves to define the environment produced by the detonation of Mk82 and 83 conventional bombs near rectangular (SCPS-2), arch (GAS), and cylindrical (AMF-80) structures. These SRS curves are based on tests conducted in dry alluvial soil composed of silty sands with intermittent caliche beds. For other soil types, the SRS could be substantially different. However, these reports (referenced below) do provide excellent information necessary for determining SRS information. SRS curves do not represent the actual floor environment but the maximum response of lightly damped system of SDOF oscillators to in-structure shock. The method of SRS for use in protective construction is currently being investigated by AFWL/NTE to determine any inaccuracies and level of conservatism.

(c) Step 3 - Locate the item of equipment being considered form Table 12-2 of the Army manual and find the shock environments it will survive. This data and most of shock tolerance of data available today does not provide a good indication of the shock tolerance of equipment. Most of the data is in terms of the SRS of the shock motions (shock tolerance spectra) that the equipment has survived in qualification (proof) type tests or analyses, i.e., tests or analyses performed at shock input levels at or below design levels, to qualify the equipment for operational service. In most cases, there is no indication of how close the shock tolerance spectra are to the shock tolerance level of the equipment. Shock tolerance spectra derived from the U.S. Army Corps of Engineers SAFEGUARD BMD program for 32 different categories of equipment are given in the following references. The shock tolerance spectra are in the form of pseudovelocity SRS versus cyclic frequency on tripartite paper:

1. Marquis, J.P., and Paez, T.L., Manual for Use of Shock Response Spectra in Assessing Equipment Survivability and Shock Isolation Requirements for Arch Structures, AFWL-TR-85-45, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, Arch 1985.

2. Marquis, J.P., and Paez, T.L., Manual for Use of Shock Response Spectra in Assessing Equipment Survivability and Shock Isolation Requirements for Bermed Rectangular Structures, AFWL-TR-86-35, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, March 1986.

(d) Step 4 - Compare the horizontal and vertical spectra obtained from Step 3 with the horizontal and vertical in-structure response spectra from Step 2 at the location where the equipment is installed.

(e) Step 5 - If the design shock environment (Step 2) falls below the environment in Table 12-2 of the Army Manual, the equipment can be hardmounted. If it exceeds the environment in Table 12-2, the designer has two options: shock isolate the equipment or shock test and retrofit if required until it survives the in-structure shock environment.

(2) Distribution: Rigid mounting of piping components to exterior wall should be avoided. Flexible piping or hoses should be used periodically along the length of piping runs, and equipment components should be installed in accordance with design procedures for shock isolating equipment. Information on the design and location of air ducts to withstand and protect against weapons effects such as CBR, overpressure and shock is given in Chapter 12 of the Army manual indicated above.

(3) Additional Reference: Vibration and isolation control is also described in further detail for HVAC equipment in the "1987 ASHRAE Handbook, HVAC Systems and Applications", Chapter 52, Sound and Vibration Control.

e. Water: Provide separate water storage facility for domestic and any required industrial water needs and emergency water for fire fighting purposes. The quantities for each of the above needs will have to be determined locally based on the mission and needs of the facility involved and the length of the contingency period. A separate water well should be provided to supply the above needs where a groundwater aquifer is available. Supplied water does not need to be potable; however, potability would be desirable if minimal treatment would result in potable quality. Where potable water cannot be obtained, bottled drinking water can be provided. Where groundwater is not available, or not feasible, water storage for the critical facility can be supplied initially from the central water distribution system. Storage capacity for the critical facility would have to be sufficient for the entire contingency period. Where two or three critical facilities are sited in close proximity to each other, a separate well and water storage facility can be centrally located to serve both or all three critical facilities. The water supply system should he protected to the same degree as the facilities served. As an alternate, water for fire fighting can be obtained from lakes or lagoons planned for this purpose. The aforementioned storage facilities (tanks) could be reduced accordingly. Another alternative which is recommended for fire protection water is the installation of a number of wells located in various areas oF the base in close proximity to designated critical facilities. Protected ground-level or below ground-level water storage tanks should be provided at each well location for connection to fire fighting equipment. Waterpumps for wells would operate on gasoline or diesel driven engine-generators. Capacity of the wells and storage tanks would be determined locally according to the critical facilities missions and needs For that installation. Water supply quantities would be based on the fire fighting strategy necessary to provide the minimum level of fire protection to critical facilities during the contingency period. The fire fighting strategy would be determined locally.

f. Wastewater. Critical Facilities generating domestic wastewater in a location where a central wastewater collection system is available shall discharge into the central wastewater collection system as the primary disposal method. A separate backup wastewater ho]ding tank should be installed in parallel off the building sewer line and valved to permit diversion of the sanitary wastewater into the holding tank. In lieu of a holding tank, the installation of a minimum treatment and disposal facility may be considered for use during the contingency period. Venting of the facilities sanitary sewer lines shall he protected against CBR contamination inside the facility where the threat of warfare exists. Venting to a controlled interior portion of the facility where the air is filtered against CBR contamination and exhausted to satisfy fresh air intake requirements should be considered. A separate drain system and collection tank should be considered for installation where CBR contaminated wastewater is expected to he encountered or generated. This would be in addition to the above mentioned holding tank.

g. Chemical-Biological-Radiation (CBR) Considerations: Appropriate protective measures should be take in areas where the threat of CBR warfare exists. In these areas, measures shall be taken to protect the facility interior environment and facility personnel from CBR contamination. Support utility components electrical generators, HVAC equipment, etc) which require outside air for operation and/or attendance should be considered for location within the protected facility for operation and monitoring accessibility, avoiding the need for CBR protective personnel equipment and entrance/exit procedures. Location of equipment inside the facility must provide for sealing off and separating outside air from the facility interior.

5. Programming. Programming of projects incorporating critical design standards contained in this ETL must be approved by HQ USAF/LEEP. Programming of these facilities will not be initiated prior to the FY 91 MCP. For projects to be included in the FY 91 MCP that have already been submitted, MAJCOMs need to identify additional costs as a result of applying criteria in this ETL, as well as identifying program offsets to accommodate the increased costs. MCP submittals must identify critical facility costs (i.e., structural, electrical, mechanical, CBR, water, sanitation, etc.) as sub-elements to the DD Form 1331. Retrofit projects to provide this protection must also provide the above cost breakout.

FOR THE CHIEF OF STAFF

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